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Restoration of the Soil and Vegetation in Sandy Land with Different Stages of Deflation

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Abstract

The aim of this work is to reveal the features of fallow sandy lands with different stages of deflation. The virgin soil-vegetation cover was the reference point: plots with light and strong deflation were compared with it. The soil deflation stages were determined by the presence or absence of layers characteristic of the background soils of the territory. The restoration of vegetation depends on the activity of wind erosion, the properties of the soils and substrata emerging on the soil surface. Studies have shown that the soil properties of deflated plots contradict the background and classical schemes of fallow land recovery.

Keywords: Trasbaikalia, Barguzin Depression, sandy lands, plant-soil cover, soil deflation, vegetation restoration

1. Introduction

In the Transbaikalia depressions of the Baikal Rift Zone, there are large sandy massifs with arid and semi-arid ecosystems. They are located more than 1.3–1.5 thousand km to the north of the steppe and desert zones. In the Barguzin Depression (Buryatia, Russia), the determining factors in the functioning of ecosystems are the relief, the extra-continental climate and alkaline sands.

Vast areas of former steppes were opened during the 1950s. These arable lands were abandoned due to low productivity at the end of the last century. These vulnerable ecosystems have either not recovered or are recovering very slowly. The processes of restoring sandy soils on the northern margin of isolated islands in the steppes of Transbaikalia have not been sufficiently studied [1, 2]. The little information available confirms the similarity of the restoration processes with thoese in the semi-desert and desert soils of Central, Anterior and Inner Asia [3–8]. The aim of the research is to study the features of restoration processes in fallow sandy soils at different stages of deflation in the northern range of the steppes of Asia.

2. Methods

The investigations were carried out in the northern boundary of the steppe (N 54–55°) in the Asian part of Russia (Republic of Buryatia). The model territory was the Barguzin Depression, an island steppe in the taiga zone. The mountains along the western and eastern parts of the depression effectively act as a barrier for moisture-bearing air masses. The climate is sharply continental with cold and prolonged winters and short and hot summers: the average annual temperature is −2.56°C [9]. Soil-forming rocks are sands formed because of the destruction of high-potassium calcium-alkaline granites in the Angara-Vitim batholiths [10, 11]. An important feature of the sands is their alkaline and strongly alkaline (8.8) reaction [11].

The flora is similar to the floras of Baikal Siberia and is characterized by the predominance of long-root plants. *Calamagrostis epigeios* (L.) Roth, *Leymus chinensis* (Trin.) Tzvel., *L. littoralis* (Griseb.) Peschkova, *L. racemosus* subsp. *crassinervius* (Kar. & Kir.) Tzvelev, *Hierochloë glabra* Trin. are most active.

Cryoaridic and cryo-humus soils dominate the steppes. Arable land contributed to the activation of deflationary processes. The soils are blown away completely by strong winds or changed by soil stratification.

Anthropogenic impact, the degree of soil transformation and the stages of digression demutation were studied in the experimental polygon-transect plots (Table 1): (i) climax (pristine) plots (P1 and P18); (ii) fallow plots, light or non-deflated soils (P8 and P11); (iii) fallows plots on *overgrown sands* (P10, P12 and P13); and (iv) fallow plots on sands not overgrown with plants (P3). Comparative-geographical, morphological, physic-chemical and agrochemical methods were used in the study of soils.

Virgin soils are very rare due to plowing everywhere in the steppe zone. Full-profile soils (P18) have a system of layers: AK-[AB]-BPL-BCA-Cca. The thickness of layers AB and BPL are about zero (P1) or less than 2–5 cm. Surface (soil) layers of virgin land have a minimum pH (7.3–7.5) of the humus layer, which indicates their stable state in the landscape. Maximum carbonates accumulate in the layer of BCA. Carbonates have a small concentration in the humus layer. The content of humus in these soils is low; the granulometric composition is dominated by sand fractions (Table 2).

Table 1: The brief characteristics of study points.

№	Geographical Coordinates	Altitude, m	Ecosystems
P1	N 54.40694° E 110.46081°	524	Slightly inclined plain with poorly expressed relief, ancient dunes. The climax plot is *Stipa krylovii* Roshev-*Carex duriuscula* C.A. Mey. steppe
P18	N 54.31881° E 110.63580°	678	Sloping plain with rugged terrain, ancient dunes, and ridge-dunes. The climax plot is *Stipa krylovii-Carex duriuscula* steppe.
P8	N 54.36539° E 110.55803°	547	Slightly inclined plain with poorly expressed relief, ancient dunes and fallow land plot with *Artemisia siversiana*.
P11	N 54.34678° E 110.60161°	591	Slightly inclined plain with poorly expressed relief, ancient dunes, and fallow land plot with *Artemisia scoparia*.
P12	N 54.34431° E 110.61269°	602	Sloping plain with rugged terrain, ancient dunes and ridge-dunes. Fallows plots with *Leymus chinensis* on overgrown sands, crest of the dune.
P13	N 54.34303° E 110.61533°	605	Sloping plain with rugged terrain, ancient dunes, and ridge-dunes. Fallows plots with *Artemisia siversiana-Artemisia scoparia*, a crest of the dune.
P10	N 54.35258° E 110.58881°	565	Sloping plain with rugged terrain, ancient dunes, and ridge-dunes. Fallows plots with *Hierochloë glabra* on overgrown sands, crest of the dune.
P3	N 54.38070° E 110.51486°	529	Slightly inclined plain with poorly expressed relief, ancient dunes. Fallow land plots on sands not overgrown with plants.

Source: Author's own work.

3. Results

Plant succession on fallow lands is very different under inactive (P8, P11) and active wind conditions (P3, P10, P12, P13). The plots of inactive wind conditions have uneven-aged (*Artemisia scoparia* and *Artemisia sieversiana*) plant communities in the rhizome stage of restoration. *Artemisia scoparia* communities have formed in conditions of limited humidity. The herbage composition consists mainly of *Artemisia scoparia* and the following species: *Carex pediformis* C.A. Mey., *Chenopodium album* L., *Convolvulus bicuspidatus* Fischer ex Link, *Setaria viridis* (L.) P. Beauv., *Lappula squarrosa* (Retz.) Dumort., *Hypecoum erectum* L., *Artemisia sieversiana*, which form communities growing under normal humidity conditions. The total projective cover (TPC) is 30%. *Artemisia sieversiana*, with 15% of projective cover, forms the first 50 cm high layer. The second layer, 25 cm high, is dominated by *Artemisia scoparia* that, together with other species, covers 10% of the area. The third layer, 15 cm high with 3% of projective cover, is mainly composed of *Dracocephalum olchonense* Peschkova, *Potentilla bifurca* L.

Table 2: Physico-chemical properties of virgin soils and fallow lads.

№	Layer	Soil Depth, cm	pH_{H2O}	CO_2	Humus	Particle Size, mm			
						1–0.05	0.05–0.01	< 0.001	< 0.01
							%		
Virgin soils									
P1	AK	0–18(20)	7.3	0.47	1.55	73	21	2	6
	BCA	18(20)–42	8.1	5.44	0.68	73	14	8	12
	BC	42–66(70)	8.9	2.53	0.21	93	3	3	4
	C	66(70)–108	8.7	2.16	0.17	86	1	2	3
	2C	108–165	8.5	2.07	0.17	85	2	2	3
P18	AK	0–23	7.5	0.47	2.21	66	22	2	12
	AB	23–29(32)	7.5	0	1.17	61	29	2	10
	BPL	29(32)–37(42)	8.1	0	1.00	60	32	4	8
	BCA	37(42)–85(90)	8.9	1.13	0.38	88	6	1	6
	C	85(90)–120	9.5	0.56	0.25	90	5	1	5
	2C	120–170	8.8	0.47	0.02	96	2	2	2
Low- and non-deflated agro-natural degraded fallow lands									
P8	Pw	0–18	7.8	0	1.33	72	20	3	8
	BPL	18–25	8.0	0.19	0.98	60	29	4	11
	BCA	25–46	8.2	6.28	0.68	67	21	7	12
	BCA-Cca	46–72	9.0	3.09	0.28	87	8	4	6
	Cca	72–90	9.2	1.87	0.21	94	3	3	3
		90–130	9.2	1.88	0.12	92	4	3	4
P11	Pw	0–19(24)	7.6	0.04	1.77	63	28	4	9
	BCA	19(24)–61(62)	8.4	4.97	0.69	69	20	7	11
	BCA-Cca	61(62)–71(74)	9.0	2.39	0.44	83	10	4	7
	Cca	71(74)–136	9.4	0.84	0.24	92	4	3	4
		136–200	8.9	0.75	0.11	95	2	3	3
Fallow plots on sands not overgrown with plants									
P3	PCca	0–22	8.4	1.78	0.12	94	3	2	3
	2Cca	22–58	8.3	2.53	0.11	96	1	2	3
	3Cca	58–125	8.2	1.97	0.10	97	1	2	2
	4Cca	125–200	8.1	1.97	0.10	96	1	3	3
Restorative and deflated arable soils									
P10	PBw	0–21	8.6	2.44	0.35	89	5	4	6
	Cca	21–55	8.8	1.50	0.20	95	2	2	3
	2Cca	55–158	8.6	1.25	0.17	95	2	2	3
	3Cca	158–200	8.7	1.50	0.14	94	2	3	3
P12	PCw	0–17(23)	7.3	0	1.09	87	8	2	4

№	Layer	Soil Depth, cm	pH_{H2O}	CO_2	Humus	Particle Size, mm			
	Cca	17(23)–93(98)	8.8	0.65	0.21	95	2	3	3
	2Cca	93(98)–184	9.0	0.75	0.16	95	1	3	3
P13	PCw	0–25(36)	7.8	0	0.45	91	5	1	4
	Cca	25(36)–90	8.9	0.84	0.22	94	2	3	4
	2Cca	90–154(160)	9.1	0.65	0.11	96	2	2	3
	3Cca	156(160)–200	8.9	0.65	0.10	96	2	2	3

Source: Author’s own work.

The obligate psamophyte *Hierochloë glabra* grows on plots with strong winds. The participation of *Hierochloë glabra* naturally decreases along with the restoration of the phytocoenosis. In the final stages of the successions, *Hierochloë glabra* completely disappears from the plant communities.

The process of natural restoration of vegetation is taking place in all territories, even in those where the processes of aeolian deflation are going on, except for active deflation ulcers. All vegetation syntaxons can be arranged along a line reflecting the natural dynamics of fixation in a sandy landscape: *Hierochloë glabra* plant communities on active ulcers of soil deflation → *Artemisia scoparia – Hierochloë glabra* → *Artemisia ledebouriana* Besser – *Hierochloë glabra* on deflated restorative soil areas.

Analysis of satellite images and the results of a ground survey in the steppe areas show that more than half of the fallow lands were deflated. This is affected more by surfaces with ancient eolian dune forms, especially the crests of dunes expressed in the relief. Active deflation ulcers are totally or partially devoid of soils and vegetation (P3). Some plots are totally (P12, P13) or partially (P10) devoid of the soil layer. Pioneering psammophyte communities prevent the movement of sands. Because of plowing and plant overgrowth, the humus content in the arable layer was higher than in rock.

Clearly, the features and speed of successions determine the soil-substrate indices, especially the level of fertility. Due to high pH (8.6) and carbonates plots (P10) create unfavorable conditions for the development of plants, soil microbiota and the accumulation of humus substance. Thus, the restoration of vegetation and species diversity is strongly hampered. The transformation of a substrate for the next stages of succession depends to a large extent on the speed of leaching of salts located in the root layer. The vegetation fixation and accumulation of humus occur much faster in leached sands (P12 and P13).

4. Conclusion

The restoration of vegetation depends on wind and the properties of the surface substrate. The irrational use of sand masses outcrops the soil before deep soil-forming rocks with unfavorable properties for vegetation, particularly pH and carbonate content. High alkalinity and carbonate content inhibit the vegetation fixation of deflation ulcers and the development of background successive stages in the fallows.

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